

Home Range and Activity Patterns by Gray Foxes, *Urocyon cinereoargenteus* (Carnivora: Canidae), in East Tennessee

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ABSTRACT—We determined home-range size, spatial distribution, and activity patterns of gray foxes (*Urocyon cinereoargenteus*) ($N = 10$) between September 1986 and August 1987 in east Tennessee. Average annual home-range size was 3.97 ± 1.51 ($\bar{x} \pm SE$) km^2 . There were no significant differences in home-range size between sexes (females 3.67 ± 1.54 ; males 4.27 ± 1.59 km^2) or age groups (adults 4.41 ± 1.46 ; subadults 3.20 ± 1.62 km^2). Home-range sizes were similar in three reproductive seasons and in seasons of predominantly fruit (presumably abundant) and predominantly flesh (presumably more scarce) diets. Home ranges of adult male–female pairs and subadults coincided, suggesting monogamy and exclusive area utilization by family groups. We observed lower sunrise and/or daylight activity levels during breeding and flesh diet seasons, and in months of low foliar cover.

The relationship of body size, metabolic needs, and dietary trophic level to home-range size is well known. Relative to body size, flesh-eaters have larger home ranges than plant-eaters, presumably due to decreasing food base with ascending trophic level (McNab 1963). However, most studies relating home-range size to trophic level are based on interspecific comparisons.

Intraspecifically, seasonal shifts in home-range size appear to be negatively correlated to food availability (Nicholson 1982). Sex, age, and reproductive cycle (MacDonald 1980), population density (Trapp and Hallberg 1975), inter- or intraspecific competition, and habitat quality and dispersion (MacDonald 1980) are also thought to play a role in affecting home-range size.

Most studies indicate that gray foxes are nocturnally active (Yearsley and Samuel 1980, Nicholson 1982, Haroldson and Fritzell 1984). However,

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the amount of time required for foraging and temporal activity patterns might be expected to change in relation to seasonal food availability and/or type.

We obtained concurrent data on food habits, home range, and activity patterns for gray foxes (Greenberg et al. 1988), which provided an opportunity to compare seasonal shifts in dietary trophic level with changes in home-range size. We predicted that home-range size would become smaller as fruit became seasonally available (spring–fall) and would expand in response to a presumably scarcer (predominantly flesh) winter food supply. We also compared reproductive seasons, sex, and age with home-range size.

METHODS

Study Area—The study area was located within the National Environmental Research Park on the Department of Energy's Oak Ridge Reservation, approximately 28 km west of Knoxville, Tennessee (35°58' N, 84°56' W). Vegetation community types included pine and pine-hardwood forests, loblolly pine (*Pinus taeda*) plantations, eastern red cedar (*Juniperus virginiana*) barrens, oak-hickory forests, bottomland hardwood forests, old fields, and developed areas. The Tennessee Valley Authority's Melton Hill Reservoir and Watts Bar Lake border the reservation on the west, south, and east; streams and springs throughout the area provided water and wetland habitat.

The geology of the reservation is characteristic of the Southern Appalachian Valley and Ridge Province. Parallel, southwest–northeast-oriented ridges separated by valleys (elevation ranged from 226 to 413 m) lend additional diversity to the landscape.

Radio Telemetry—Foxes were captured in Number 1.5 Victor soft-catch leg-hold traps with dirt-hole sets and drags. Attractants included fox urine, fox gland lures, pork cracklings, fish oil, and muskrat oil. Foxes were anesthetized with 5–10 mg/kg ketamine hydrochloride (Ketaset) or not anesthetized (Nicholson 1982). Animals were eartagged, fitted with radio collars equipped with a mercury tip-switch activity sensor (Telonics, Mesa, Arizona) in the 150–151.84 frequency range, and released at the trap site. We classified foxes as subadults (<1-year-old) or adults based on tooth wear (Geir 1968).

There were 138 receiving stations established. Animals were located with a four-element, hand-held, Yagi antenna and a portable receiver. Locations and activities were recorded at 2-hour intervals between the hours of 1600 and 0800 weekly. Occasional locations were also recorded between 0800 and 1600. We used ≥ 2 compass

bearings with an intersecting angle $\geq 45^\circ$ and $\leq 135^\circ$, and as close to 90° as possible (Heezen and Tester 1967) to plot locations. Activity was recorded. Azimuths were converted to x:y coordinates by the computer program Convxpoly (Boyle 1986), and the data were hand-plotted on a 1:24,000 United States Geological Survey topographic map with the Universal Transverse Mercator grid system.

We estimated home-range sizes by the minimum convex polygon method (Mohr 1947). Atypical peripheral locations (known excursions) were excluded based on subjective knowledge of typical home-range use by the authors (Ables 1968).

Smith et al. (1981) found that three half-night radio-tracking periods provided a larger estimate of coyote home ranges than 30 independent daily locations, and that three or four nights provided good home-range estimates for coyotes with small home ranges. We assumed that their findings also applied to gray foxes. Hence, we considered ≥ 25 locations and at least three track-nights to be an adequate sample size for home-range determinations.

Home ranges were calculated for three reproductive and two dietary seasons. Three reproductive seasons included breeding (January–March), pup-rearing (April–June), and nonbreeding (July–December) (Sullivan 1956, Nowak and Paradiso 1983). Dietary seasons included a dominantly flesh diet (January–April) and dominantly insect or fruit diet (May–December) (Greenberg and Pelton 1991). We compared annual and seasonal home-range sizes between sexes and age groups. Due to small sample sizes and high variance, we used descriptive statistics rather than statistical tests in drawing our conclusions.

We calculated the percentage of "active" locations within four time periods: two at sunrise (0.5 hours prior, 0.5 hours after sunset) and two at night (0.5 hours after sunset, 0.5 hours prior to sunrise). Data were pooled for all animals. We used Chi-square tests to detect temporal differences in activity level, differences among reproductive and dietary seasons, and differences between seasons of low (November–April) and high (May–October) foliar cover.

RESULTS

We obtained 2,247 locations on 12 foxes captured between September 1986 and August 1987 (Fig. 1 and 2). Five adult males, two adult females, and five subadult females were captured. Only 10 animals were included in home-range estimates. Because of variable tracking periods among foxes, some animals could not be used in home-range estimates of reproductive or dietary seasons (Table 1).

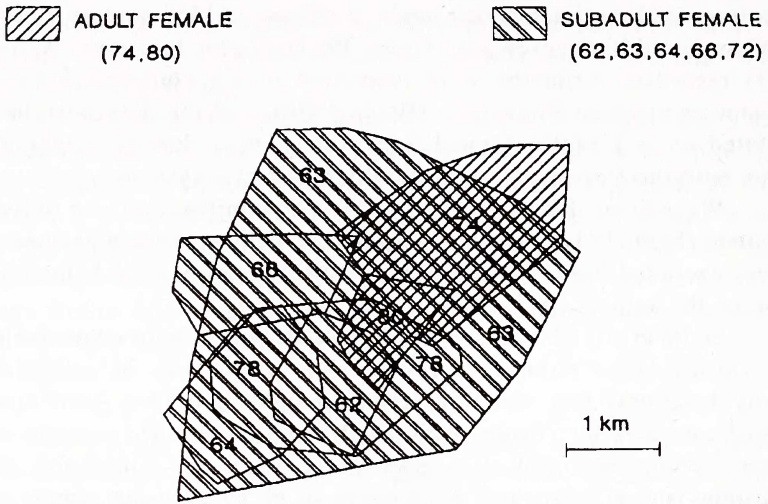


Fig. 1. Composite home ranges of two adult and five subadult female gray foxes on the Oak Ridge Reservation in east Tennessee, September 1986–August 1987.

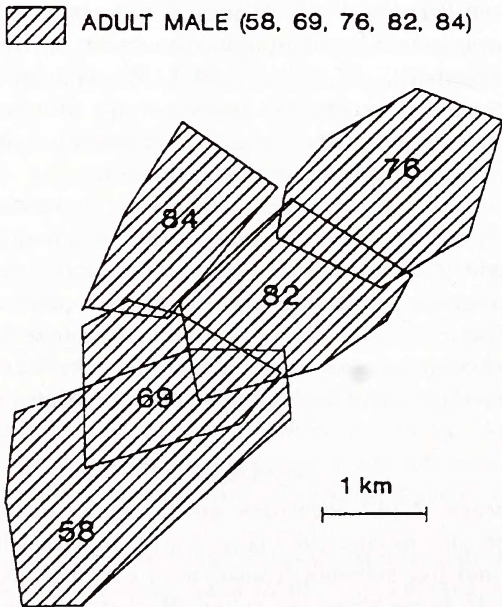


Fig. 2. Composite home ranges of five adult male gray foxes on the Oak Ridge Reservation in east Tennessee, September 1986–August 1987.

Table 1. Annual minimum cover polygon home-range estimates (km²) for five male and seven female gray foxes radiotracked from September 1986 to August 1987, Oak Ridge Reservation in east Tennessee.

ID	Sex	Age	Number of Locations	Tracking Period	Annual Home-Range Size (km ²)
58	M	Adult	25	03/16/87-08/31/87	6.91
69	M	Adult	231	09/25/86-06/09/87	3.25
76	M	Adult	248	09/14/86-08/31/87	4.36
82	M	Adult	293	09/07/86-08/31/87	4.01
84	M	Adult	130	09/11/86-03/02/87	2.83
62	F	Subadult	102	10/01/86-01/12/87	2.09
63	F	Subadult	119	02/25/87-08/31/87	17.94 ^{1,2,3}
64	F	Subadult	236	09/26/86-05/12/87	3.08
66	F	Subadult	271	09/25/86-08/31/87	2.09
74	F	Adult	266	09/14/86-08/31/87	5.08
78	F	Subadult	308	09/19/86-08/31/87	5.54
80	F	Adult	18	09/09/86-11/03/86	1.24 ^{1,2,3}

¹ Omitted from reproductive season home-range analysis; insufficient data.

² Omitted from dietary season home-range analysis; insufficient data.

³ Omitted from annual home-range analysis; insufficient data.

Mean annual home-range size ($\bar{x} \pm SE$) for 10 gray foxes was 3.97 ± 1.51 km². Home-range size was similar between males ($N = 5$; 4.27 ± 1.59 km²) and females ($N = 5$; 3.67 ± 1.54 km²), and between adult ($N = 6$; 4.41 ± 1.46 km²) and subadult ($N = 4$; 3.20 ± 1.62 km²) foxes.

Home-range size was similar during fruit diet ($N = 9$; 2.92 ± 0.40) and flesh diet seasons ($N = 9$; 3.43 ± 0.48). Home-range sizes were similar among reproductive seasons for all foxes ($N = 8$; 2.72 ± 0.17); ($N = 7$; 2.32 ± 0.43); and ($N = 9$; 2.83 ± 0.42) for breeding, pup-rearing, and pre-breeding seasons, respectively. Within reproductive seasons, male and female home-range sizes also were similar ($N = 4$; 2.67 ± 0.11) versus ($N = 4$; 2.7 ± 0.30) for breeding; ($N = 3$; 2.79 ± 0.59) versus ($N = 4$; 1.98 ± 0.55) for pup-rearing; and ($N = 4$; 2.60 ± 0.30) versus ($N = 5$; 3.01 ± 0.67) for pre-breeding seasons, respectively. We observed that whelping females exhibited restricted movements during pup-rearing season.

Adjacent home ranges of four adult males were nearly exclusive except for excursions by M 69 and M 76 into M 82's home range during breeding season (Fig. 2). Subadults F 64, F 62, and F 78 home ranges were contained within adult M 69's home range; F 64 and

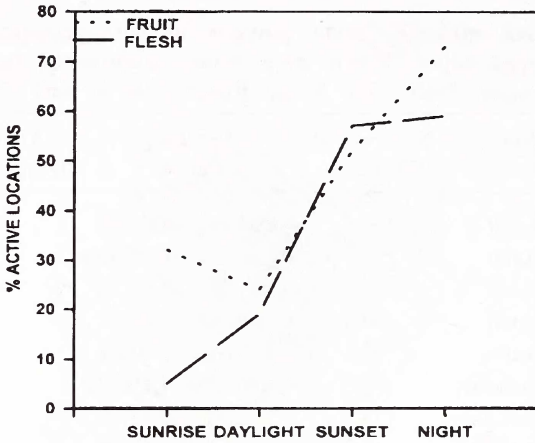


Fig. 3. Diet-related (fruit versus flesh) activity levels (%) of gray foxes radiotracked on the Oak Ridge Reservation in east Tennessee, September 1986–August 1987.

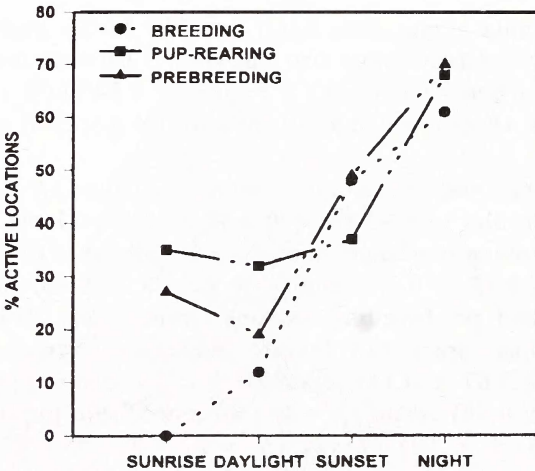


Fig. 4. Reproduction-related activity levels (%) of gray foxes radiotracked on the Oak Ridge Reservation in east Tennessee, September 1986–August 1987.

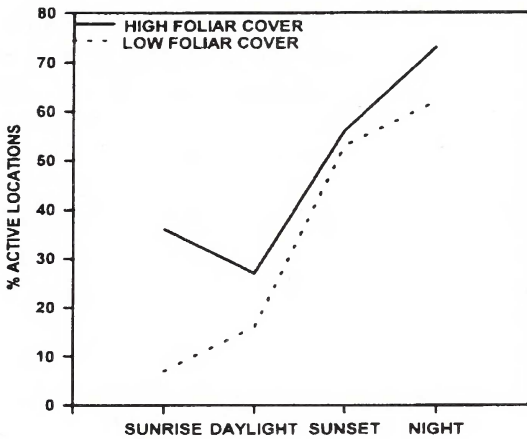


Fig. 5. Cover-related activity levels (%) of gray foxes radiotracked on the Oak Ridge Reservation, east Tennessee, September 1986–August 1987.

F 62 alternately used the same resting places. Adult male–female pairs sharing home ranges include M 82 with F 80 (who died before an adequate sample size was obtained for inclusion in home-range analysis) and M 76 with F 74. Adult same-sex fox home ranges overlapped little, whereas adult male–female pairs and adult–subadult home ranges overlapped substantially. Subadult F 63 had an aberrantly large “home range,” which may have been explorations instead of a home range at all.

Gray foxes were active on a greater proportion of locations in evening and night hours than during sunrise and daylight hours. Animals exhibited a lower sunrise activity level during flesh diet than fruit diet season ($\chi^2 = 17.8$, $P < 0.0005$) (Fig. 3). Lower sunrise activity levels were observed during breeding season, and higher daylight activity was observed during pup-rearing season than during other reproductive seasons ($\chi^2 = 29.8$, $P < 0.0005$) (Fig. 4). Lower sunrise and daylight activity levels were observed during months of low foliar cover than during months of high cover ($\chi^2 = 32.3$, $P < 0.0005$) (Fig. 5).

DISCUSSION

Gray fox home-range sizes were within the range of those reported in other studies (Richards and Hine 1953, Fuller 1978, Yearsley and Samuel 1980, Nicholson 1982, Hallberg and Trapp 1984, Haroldson and Fritzell 1984, Wooding 1984). Nearly exclusive home

ranges shared by adult male-female pairs and subadults suggested that family units are spatially segregated. However, this conclusion is tentative because uncollared foxes may have lived undetected within the study area. Trapp and Hallberg (1975) suggest that a family shares a home range exclusive of others, and they provide some evidence for territoriality.

We were unable to detect any influence of seasonal dietary composition or dietary trophic level on home-range size. Instead, we suggest that diverse, interspersed habitat types within home ranges might provide sufficient food supply in all seasons. Maintaining a home range encompassing sufficient habitat area and types to provide a year-round food supply might be a better strategy than shifting home-range size in response to fluctuating patch productivity or food availability (MacDonald 1980). Further study, including a larger sample size, is warranted to determine the influence of seasonal diet on gray fox home-range size.

Trends in home-range size indicate that males may range farther than females during breeding season. High variance and small sample size may obscure detection of seasonal differences in patterns of home-range size or differences among age groups or sexes.

Predominantly nocturnal activity has been reported in other studies (Nicholson 1982). Lower levels of sunrise activity during flesh diet season, breeding season, and months of low foliar cover could all be a response to sparse cover (November-April). Energy conservation during a period of lower food availability may be a factor. Higher daylight activity during pup-rearing season than during other seasons might be due to increased energy requirements for both parents and pups.

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LITERATURE CITED

- Ables, E. D. 1968. Ecological studies on red foxes in southern Wisconsin. Ph.D. Thesis. University of Wisconsin, Madison.
- Boyle, K. A. 1986. A comparison of methods of home range analysis. M.S. Thesis, Clemson University, Clemson, South Carolina.
- Fuller, T. K. 1978. Variable home-range sizes of female gray foxes. *Journal of Mammalogy* 59:446-449.
- Greenberg, C. H., and M. R. Pelton. 1991. Food habits of gray foxes (*Urocyon cinereoargenteus*) and red foxes (*Vulpes vulpes*) in east Tennessee. *Journal of the Tennessee Academy of Science* 66(2):79-84.
- Greenberg, C. H., M. R. Pelton, and P. D. Parr. 1988. Gray fox ecology in the Oak Ridge National Environment Research Park: food habitats, home range, and habitat use. Environmental Sciences Division Publication No. 3101.
- Geir, H. T. 1968. Coyotes in Kansas. Kansas State College Agricultural Experiment Station Bulletin 393.
- Hallberg, D. L., and G. R. Trapp. 1984. Gray fox temporal and spatial activity in a riparian agricultural zone in California's Central Valley. Pages 920-928 in *California riparian systems: ecology, conservation, and productive management*. (R. E. Warner and K. M. Hendrix, editors). University of California Press, Berkeley.
- Haroldson, K. J., and E. K. Fritzell. 1984. Home ranges, activity, and habitat use by gray foxes in an oak-hickory forest. *The Journal of Wildlife Management* 48:222-227.
- Heezen, K. L., and J. R. Tester. 1967. Evaluation of radio-tracking by triangulation with special reference to deer movements. *The Journal of Wildlife Management* 31:124-141.
- MacDonald, D. W. 1980. Resources dispersion and the social organization of the red fox (*Vulpes vulpes*). Pages 918-949 in *Worldwide Furbearer Conference Proceedings, Volume II* (J. A. Chapman and D. Pursley, editors). Frostburg, Maryland.
- McNab, B. K. 1963. Bioenergetics and the determination of home-range size. *American Naturalist* 97:133-140.
- Mohr, C. O. 1947. Table of equivalent populations of North American small mammals. *American Midland Naturalist* 37:223-249.
- Nicholson, W. S. 1982. An ecological study of the gray fox in east central Alabama. M.S. Thesis, University of Georgia, Athens.
- Nowak, R. M., and J. L. Paradiso. 1983. Walker's mammals of the world. Volume 2. Fourth Edition. The Johns Hopkins University Press, Baltimore, Maryland.
- Richards, S. H., and R. L. Hine. 1953. Wisconsin fox populations. Wisconsin Conservation Department Technical Wildlife Bulletin Number 6.

- Smith, G. J., J. R. Cary, and O. J. Rongstad. 1981. Sampling strategies for radio-tracking coyotes. *Wildlife Society Bulletin* 9:88-93.
- Sullivan, E. G. 1956. Gray fox reproduction, denning range, and weights in Alabama. *Journal of Mammalogy* 37:346-351.
- Trapp, G. R., and D. L. Hallberg. 1975. Ecology of the gray fox. Pages 164-178 *in* *The wild canids* (M. W. Fox, editor). Van Nostrand Reinhold Company, New York, New York.
- Wooding, J. B. 1984. Coyote food habits and the spatial relationship of coyotes and foxes in Mississippi and Alabama. M.S. Thesis, Mississippi State University, Starkville.
- Yearsley, E. F., and D. E. Samuel. 1980. Use of reclaimed surface mines by foxes in West Virginia. *The Journal of Wildlife Management* 44:729-734.

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